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## PROGRESS REPORT ON MATERIALS AND TEST METHODS

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This report tries to review briefly Japanese progress in the materials and test methods since the last UJNR meeting. Material is perhaps one of the subfield of fire safety science in which application of engineering concept to fire safety design, regulation and assessment is still very young, while fire safety engineering has already been brought into practice in structural fire safety and smoke control. In the last three years since the previous UJNR meeting, there have been continuous research efforts on materials and testing methods in fire chemistry, building fire safety, and material industry as there had been before. However, perhaps start of the Ministry of Construction's R & D Project(MOC So-pro) on the development of assessment methods of fire safety performance in 1993 is becoming a locomotive driving research and development on materials and testing methods especially in building area.

### Ignition/Ignitability

Condition for the ignition due to arc welding particles was studied experimentally using high speed video camera(Kinoshita et al, 1995). Arc welding apparatus was operated and arc welding particles were sampled on a gauze sheet soaked with liquid fuel covering a tray located 0.5 m ~ 2.0 m away from the arc welding unit. Gauze sheet was used to prevent decay of the arc welding particles before sampling. Since large numbers of particles flew on the gauze sheet, the particle which actually ignited the liquid fuel was identified by the high-speed video camera and was sampled. Dimension and weight of each particle identified as the igniter was analyzed, and the equivalent diameter and weight of the smallest particle thus identified at each distance from the welding unit was defined as the critical diameter and the critical weight for ignition respectively. The critical diameter and the critical weight for ignition thus defined were found to be increasing functions of distance. Equivalent density for this critical condition seemed to be independent of distance.

### Noncombustibility

The current Japanese regulation on building fire safety specifies noncombustible materials according to the results of the *noncombustibility test*(MOC Notification No.1828) and the *surface test*(MOC Notification No.1231). The Notification No.1828 *noncombustibility test* was developed according to a draft British Standard which later became ISO 1182, and its apparatus is essentially very close to the ISO 1182 noncombustibility test apparatus. The both test methods adopt temperature rise as one of the indicators for fire safety assessment, which is however defined in different way between the two tests. Comparison of the Notification No.1828 *noncombustibility test* and the ISO 1182 noncombustibility test on 14 identical materials was carried out to explore replacement of the Notification No.1828 *noncombustibility test* in the Japanese building regulation(He et al 1995). According to this comparison, temperature rise value as index for the assessment was always lower at the ISO 1182 than at the Notification No.1828 *noncombustibility test*. However, except for highly noncombustible materials such as metal, tested materials were graded in very similar order by the two test methods. It seems to suggest high interchangeability between the Notification No.1828 *noncombustibility test* and the ISO 1182. Benefits of the ISO 1182 noncombustibility test relative to the No1828 *noncombustibility test* include resolution of

apparent heat generation typically for metal due to low density, and its drawback includes relatively long time for manipulation.

Relevance of the results of the Notification No.1828 *noncombustibility test* with heat release has been studied on asbestos-substitute materials(He et al 1994). Some clear correspondence has been confirmed between the index temperature(maximum temperature in the furnace) and the maximum heat release rate measured with the oxygen consumption method.

### **Heat Release Rate**

Heat release rate is considered one of the key parameters controlling flame spread in fire. Many fire models for flame spread and room fires use heat release data from the ISO 5660 Cone Calorimeter. However, since the flame heat transfer is a size-dependent process, there has been question if such bench-scale test as the Cone Calorimeter can reproduce heat release in full scale fire. A comparative study between the Cone Calorimeter and an intermediate scale vertical electrical radiant panel has been made to clarify scale effects on the heat release rate(Hasemi et al 1995). According to this result, discrepancy between heat release rate by the Cone Calorimeter and by the intermediate panel becomes significant as the heat flux level to the specimen is reduced.

Another analysis using the Cone Calorimeter with the level of heat flux and the preheating condition as the experimental parameters demonstrated considerable dependence of heat release rate on the preheating condition which was represented by the surface temperature of the specimen just before the ignition(Kikuchi et al 1994).

### **Gas Toxicity**

Development and popularization of halogen-free fire retardant has been an important subject in fire chemistry during the last decade. However, it is widely recognized that performance of fire retardant often is not consistent with other safety aspects such as corrosivity and toxicity. Naba et al studied generation characteristics of phosphine and other toxic products from plastics containing red phosphorus as fire retardant using a quartz-tube furnace anticipating possible phosphine generation in fire through reaction between red phosphorus and water vapor. They used EVA, Nylon, PVC and LDPE with and without red phosphorus, and evaluated contribution of toxic gas component by the ratio of  $C_x/LC_{50-x}/(\sum C_i/LC_{50-i})$  with literature values of  $LC_{50}$ . According to their analysis, contribution of phosphine was rather minor, generally not larger than 6%, for each plastic they used. Generation of HCN and CO was weaker for FR Nylon with red phosphorus than without red phosphorus whereas FR EVA generated more CO than EVA.

### **Pyrolysis**

Pyrolysis of Polyimido, one of metal substitute polymers, at high temperatures anticipated in fire and influence of oxygen concentration on the pyrolysis was studied with TG-DTA/MS (Asai et al, 1995). 100  $\mu$  m thick Kapton sheets were used as the specimens. At 0% oxygen atmosphere, pyrolysis started at around 530C, and the maximum weight loss rate appeared at around 580C. Approximately 60% of the initial weight remained as black residue. In atmospheres with oxygen, although there is a peak weight loss rate at around 580C, there was always a secondary peak of pyrolysis at between 610C and 800C. Estimated activation energy was far higher at the first pyrolysis step than at the second step, and the activation energy at the first step was found to decrease with increasing the oxygen concentration.

## So-pro Activities on Materials and Testing

So-pro subprogram on materials is trying to coordinate Japanese fire tests on materials with international standards and make framework of material fire safety assessment consistent with fire safety engineering concept. The So-pro subprogram on materials consists of two working groups, one supported by the material industry and the other supported by construction industry. The first working group started in 1993 deals with testing methods and invites experts mainly from fire testing laboratories, whereas the second working group started in 1995 invites experts from construction companies and deals mainly with application of test data to fire safety design and fire safety evaluation of post-construction conditions of building products. Figure 1 is a framework for the relation between fire safety design and material tests used as the guide for the current So-pro material subprogram, which includes various activities such as

- ①technical survey, development and practice with international standard fire tests
- ②development of tests on reaction-to-fire performances not yet standardized by ISO
- ③quantification of design parameters for the influence of construction, configuration and other postfabricated conditions of building products on fire growth
- ④validation of fire growth models
- ⑤comparison of test results between Japanese current fire tests and international standard tests
- ⑥development of matrix method for the classification and assessment of lining materials based on the fire safety engineering concept

The activity ① includes interlaboratory trials on ISO reaction-to-fire tests which are now carried out as an international cooperation as a CIB W14 subprogram. Results of the previous interlaboratory-trials carried out within the So-pro framework has been published(Marchal et al 1995). A series of fire tests from bench-scale to full-scale including research oriented ones on over 15 materials are run for the purpose of ②,③,④, and ⑤. It is planned that existing fire growth models be validated against the tests. The matrix method for the assessment of material fire safety is planned to be developed by simulating fire growth and evacuation in fire for different conditions of buildings such as use and size. Some of the recent works introduced in respective reaction-to-fire performance have been carried out within the So-pro framework.

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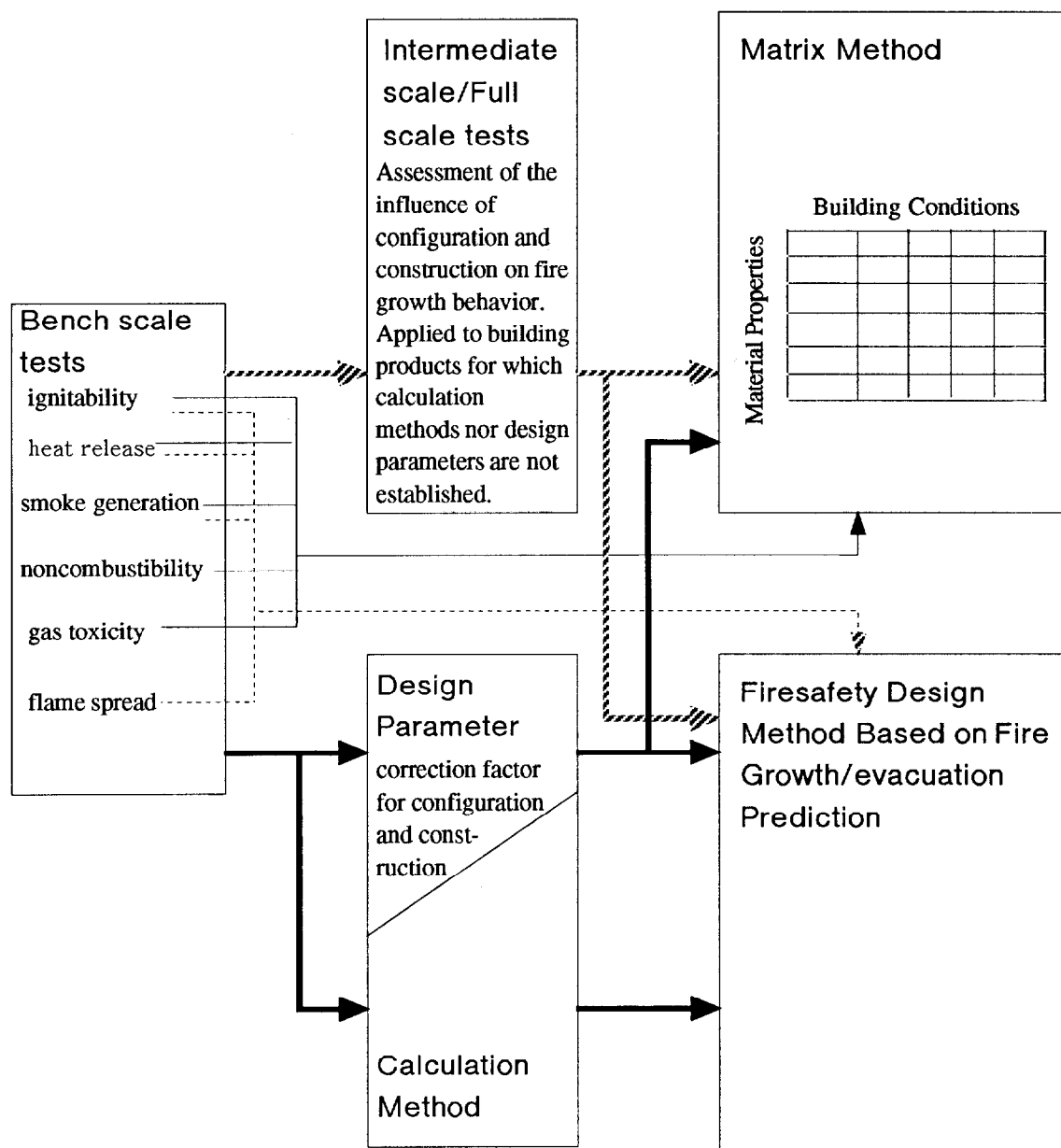
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\* The references thus marked are written only in the Japanese language.

Figure 1

## So-pro Proposed Firesafety Assessment Framework on Lining Materials



The following two approaches of fire safety desing are considered.

①Application of prediction method

②Matrix method

The first approach will perhaps be applied only to special design or big construction projects, and most of practical design will be done according to the second approach. Both design methods should basically use data from same tests. Screening tests such as the noncombustibility and gas toxicity tests are to be used essentially for the second approach. The first approach may use additional tests necessary for FSE calculation. Assessment should primarily be based on benchscale tests(→ in the diagram). Intermediate and full scale tests will be applied only to building products for which bench-scale tests cannot lead to rational assessment of fire safety.